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(54) **A fluxional force-generated sound reducing device.**

(57) Fine fibers 5 are planted on a surface of an object 1 moving relative to a fluid or on an inside surface of a pipe or duct 2 conveying a fluid thereth-rough at a portion which comes into contact with the fluid. 1) When a turbulent flow from the upstream side collides with the surface covered with the fibers,

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the fibers 5 function as a cushion so as to soften the vortexes and reduce pressure fluctuations. 2) The boundary layer near the surface may easily be transformed into a turbulent flow by the fine fibers 5 so that the flow becomes less spatially correlated. Further, when any generated turbulent flow passes by, pressure fluctuations can be reduced by the fibers. 3) Each fiber is very fine and soft, and therefore does not exerts any reaction forces (or any pressure fluctuations) against the flow. As a result, the sound arising when the flow collides with the fibers is extremely softened.

FIG. 1

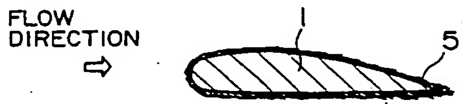
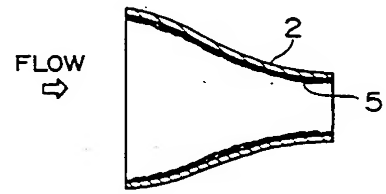


FIG. 2



BACKGROUND OF THE INVENTION

(1) Field of the Invention

The present invention relates to a fluxional force-generated sound reducing device for reducing sound generated by an object moving relative to a fluid or by a pipe, duct or the like conveying a fluid.

(2) Description of the Related Art

Conventionally, when an object made from metal or resin is placed in fluid relatively moving thereto, it has been disposed in the fluid with its hard surface exposed to the fluid. Also, the hard inside surface of conventional pipes or ducts made from metal or resin for conveying fluids is exposed to the fluid. Therefore, this relative movement between the fluid and the wall surface brings about fluxional force-generated sound. In order to reduce the fluxional force-generated sound, various techniques have been made such as smoothing the surface of the object to make a fluid flow smoothly. Alternatively, as to an object moving in a fluid, such as a wing, a trailing edge of the wing is made thin to reduce trailing vortexes to be generated (see Fig.45A) or the trailing edge may be provided with serration in order to weaken the correlation of perpendicular components of the trailing vortexes with respect to the flowing direction of the fluid (see Fig.45B). Further, it is possible to provide tripping wires on the surface of a rigid body so as to promote turbulent flow to occur (see Fig.45C).

In addition, in the opening end portion of pipes or ducts, etc. the edge is serrated in order to reduce the correlation of perpendicular components of the trailing vortexes with respect to the flow direction of the fluid as well as to promote jet mixing (see Fig. 45D).

In general, it is believed that fluxional force-generated sound occurs because of pressure fluctuations on an object surface or inner wall surface of pipes, ducts, etc. due to boundary layer turbulence on the surface of the object or the inside surface of the pipes, ducts, etc. or due to turbulent flow on the upstream side of the flow. Also, the noise is believed to be generated by pressure fluctuations induced at a trailing edge of an object or in the vicinity of an opening end portion of a pipe or duct due to trailing vortexes produced by the outflow at the trailing edge or by the outflow from the opening end portion of the pipe or duct, etc.

The fluxional force-generated sound can be reduced when any of the following conditions are attained. That is, the sound can be reduced by:

1) reducing the turbulence itself;

2) reducing the pressure fluctuations induced on the object surface by the turbulence; or

3) making smaller the area of correlation of pressure fluctuations induced on the object surface due to the turbulence, so that the energy of the pressure fluctuations may be converted into sound energy to a smaller extent.

However, it has been impossible to reduce the fluxional force-generated sound to a sufficiently low level with the aforementioned measures shown in Figs.45A to 45D.

SUMMARY OF THE INVENTION

The present invention has been proposed under the consideration of the above problems, and it is an object of the present invention to provide a fluxional force-generated sound reducing device which is capable of sharply reducing fluxional force-generated sound arising from an object placed in a fluid moving with respect thereto or from a pipe or duct conveying a flowing fluid. Hereinbelow, fluid means liquid or gas, or a mixture of gas, liquid and solid particles in any possible combinations.

In order to achieve the above object, in accordance with one aspect of the present invention, a fluxional force-generated sound reducing device is constructed such that fine fibers are planted on the object surface which is in contact with a fluid and moving relative to the fluid or on the inside surface of a pipe or duct through which a fluid is flowing. Alternatively, a fur-like material having fine fibers planted thereon may be disposed over the surface of an object or the inside surface of a pipe or duct.

In accordance with another aspect of the present invention, a fluxional force-generated sound reducing device is constructed such that a porous material is provided in or on the surface of an object which comes into contact with a fluid and moving relative to the fluid, or in or on the inside surface of a pipe or duct conveying a fluid flowing therethrough, and fine fibers are planted on the surface of the porous material. Alternatively, a fur-like material having fine fibers planted thereon may be disposed over the surface of the porous material.

In accordance with a further aspect of the present invention, a fluxional force-generated sound reducing device is constructed such that an object contacting a fluid and moving relative to the fluid or a pipe or duct, etc. conveying a fluid is formed of a porous material and fine fibers are planted on the surface of the porous material. Alternatively, a fur-like material having fine fibers planted thereon may be disposed over the surface of the porous material.

In accordance with still another aspect of the present invention, a fluxional force-generated sound reducing device is constructed such that fine fibers are planted in a trailing edge of an object contacting a fluid and moving relative to the fluid or in an opening end portion of a pipe or duct conveying a fluid flowing therethrough. Alternatively, a fur-like material having fine fibers planted thereon may be disposed over such portions as mentioned just above. In the thus constructed trailing edge or the opening end portion, it is possible to form the surface of the fine fiber material substantially in level with the surface of the object or the inside surface of the pipe or duct. Further, it is also possible to provide a porous material layer in the trailing edge of the object or the edge of the pipe or duct and fur the surface of the porous material with fine fibers.

In accordance with the devices of the present invention, the following effects can be realized.

(1) In the case where fine fibers are planted directly on the surface of the an object or the inside surface of a pipe, etc.:

(a) When a turbulent flow from the upstream side collides with the object surface or the inside surface of the pipe, etc., the fine fibers function as a cushion so as to soften the vortexes due to the collision so as to reduce pressure fluctuations.

(b) The boundary layer near the surface of the object or the inside surface of the pipe, etc. may easily be transformed into a turbulent flow by the fine fibers so that turbulences become less spatially correlated in the flow. Further, when any generated turbulent flow passes by, pressure fluctuations can be inhibited in the same manner as described above.

(c) Each fiber is extremely fine and soft, and therefore does not cause any reaction forces (or pressure fluctuations) going against the flow. As a result, the sound arising when the flow collides with the fibers becomes extremely small.

(d) When fine fibers are provided on a porous material or when an object or pipe itself is made from a porous material with fine fibers planted thereon, the porous material adds a further cushioning effect. Besides, the porous material has functions of absorbing pressure fluctuations and allowing the fluid to permeate to the other side thereof, whereby the fluxional force-generated sound can be further reduced.

(2) In the cases where fine fibers are provided in a trailing edge of an object or in an opening end portion of a pipe, etc.:

(a) The boundary between the object (rigid body) and the fluid is made obscure, and therefore the generation of strong trailing vortexes is prevented.

(b) In the above case, the sound generated from the fine fibers themselves can be inhibited to a great degree because of the same reason described in (a) above for an object disposed in a flow or pipes or ducts through which a fluid flows.

(c) When a porous material is provided at the trailing edge of the object or the end portion of the pipe, etc. with fine fibers planted thereon, the above effects can be further enhanced, and it is expected that pressure fluctuations generated around the trailing edge or the end of the pipe can be further absorbed by the porous material.

Fine fibers that can be used in the present invention are not restricted to specific types as long as they are sufficiently fine and soft to reduce unwanted sound generated by fluxional forces. They can, for example, be natural fibers, such as animal or plant fibers, or chemical fibers. Perhaps less preferable, but fibers made of natural or synthetic rubber and those made of metal may also be used.

These fibers can be planted or glued onto a surface of a rigid body directly, or they can be planted on a suitable base sheet material and the cloth-like material with fibers planted thereon may be placed on the rigid body. Alternatively, an animal fur or boa or flannel cloth may be used and attached to the surface which comes into contact with flowing fluid.

Also, the length of the fibers should be determined depending on the type of the fluid to be dealt with. For example, if the fluid is air, the length of the fibers should be between 0.5 mm and 50 mm and preferably around 10 mm. For water, the length of the fibers should also be between 0.5 mm and 50 mm.

The thickness of the fibers may be between 10 μm and 1.0 mm. For the fiber materials mentioned above, the diameter of the fiber is preferably 0.1 mm to 0.5 mm. Fibers made of metal may not be thicker than 0.5 mm in diameter.

The amount of fibers per area surface would be 5% to 70%, and preferably 10% to 50%, measured as a percentage of the sectional area of each fiber times the number of planted fibers per unit area of a surface which is covered by the fibers.

The physical properties of the fibers can be chosen depending of the fluid or the flow speed at a particular position. The fibers should be soft enough to bent, though not in a discontinuous manner, when they come into contact with the fluid. They should not produce noise due to collisions

among themselves, particularly in a frequency range at which noise should be reduced.

If the fibers are planted on a surface of a rigid body, they may be directly attached at one end onto the surface using any suitable adhesive material or a thermosetting resin adhesive. Also, the surface of a rigid body may be shaved by a given depth which may be 10% to 90% of the length of the fibers. Fibers may be directly fixed onto the shaven surface using an adhesive or a thermosetting resin adhesive, or may be inserted at one end into a layer of an unset adhesive disposed on the shaven surface. The thickness of the adhesive layer may preferably be around 10% of the length of the fibers, but can be considerably varied depending on types of the adhesive and fibers. Alternatively, fine fibers may be plated on a base sheet material, such as cloth or leather or a synthetic resin sheet, using an adhesive, and then the base material with the planted fibers can be fixed to the surface of a rigid body or a porous material using, for example, an adhesive. One end of fibers may also be woven into the base material.

The length of fibers which are exposed from the surface of an object or the surface of the base sheet material may be 10 to 90% of the length of the fibers.

Porous materials that can be used in the present invention are too numerous to mention all, and include, for example, porous plates, such as punching metal, which may have a sound absorbing material or air layer on their back side. The pore diameter should be 10 mm or less, and the ratio of openings to the total surface area should preferably be more than 30%. Also, metal mesh which has openings covering 30% or more of the total surface with or without an sound absorbing material or air layer on their back side. Further, porous metals, porous concretes and porous boards may be used as the porous material for the present invention, with or without a sound absorbing material or air layer on their back side. Still further, a sound absorbing material which are reinforced with cloth or metal mesh to improve surface rigidity. These porous materials have a higher acoustic transmissivity and an improved acoustic absorptivity than normal rigid walls.

When fine fibers are disposed on a porous material, they should be securely fixed on the surface of the porous material without closing small openings the porous material has. The adhesive for this purpose has to be chosen to provide stronger adhesion. For the purpose of the calculation of desired coverage of the surface with fibers mentioned above, the opening portions of porous materials are excluded. If fine fibers are planted on a base sheet material and the base material with the planted fibers is fixed to porous material with an adhesive, the base material should have a good breathability, and it should be fixed to a porous material so as to maintain a good breathability. The choice of an adhesive has to be made to satisfy these conditions and also provide strong adhesive strength.

The angle of planted fibers with respect to a surface the fibers cover should preferably be around 90 degrees (perpendicular to the surface), but may be varied within 45 degrees from the direction perpendicular to the surface with sufficient sound reducing effects.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig.1 is a vertical sectional side view showing Example 1 of a fluxional force-generated sound reducing device of the present invention;

Fig.2 is a vertical sectional side view showing Example 2 of a fluxional force-generated sound reducing device of the present invention;

Fig.3 is a graph representing the effect of sound reduction in Example 2;

Fig.4 is a vertical sectional side view showing Example 3 of a fluxional force-generated sound reducing device of the present invention;

Fig.5 is a vertical sectional side view showing Example 4 of a fluxional force-generated sound reducing device of the present invention;

Fig.6 is a vertical sectional side view showing Example 5 of a fluxional force-generated sound reducing device of the present invention;

Fig.7 is a vertical sectional side view showing Example 6 of a fluxional force-generated sound reducing device of the present invention;

Fig.8 is a vertical sectional side view showing Example 7 of a fluxional force-generated sound reducing device of the present invention;

Fig.9 is a vertical sectional side view showing Example 8 of a fluxional force-generated sound reducing device of the present invention;

Fig.10 is a vertical sectional side view showing Example 9 of a fluxional force-generated sound reducing device of the present invention;

Fig.11 is a vertical sectional side view showing Example 10 of a fluxional force-generated sound reducing device of the present invention;

Fig.12 is a vertical sectional side view showing Example 11 in which a device of the present invention is applied to a blow-off opening of a duct;

Fig.13 is a vertical sectional side view showing Example 12 in which a device of the present invention is applied to a blow-off opening of a duct;

Fig.14 is a vertical sectional side view showing Example 13 in which a device of the present invention is applied to a blow-off opening of a

duct;

Fig.15 is a graph schematically showing a relation between the distance 'X' covered by a fur-like material and the sound reduction effected by the example shown in Fig.14;

Fig.16 is a vertical sectional side view showing Example 14 in which a device of the present invention is applied to a blow-off opening of a duct;

Fig.17 is a graph showing sound reduction effects as a function of sound frequencies in Examples 11 through 14;

Fig.18 is a vertical sectional side view showing Example 15 in which a device of the present invention is applied to a collector placed downstream of a blow-off opening of a duct;

Figs.19A and 19B are views showing Example 16 in which a device of the present invention is applied to a collector placed downstream of a blow-off opening of a duct;

Figs.20A and 20B are views showing Example 17 in which a device of the present invention is applied to a collector placed downstream of a blow-off opening of a duct;

Figs.21A and 21B are views showing Example 18 in which a device of the present invention is applied to a collector placed downstream of a blow-off opening of a duct;

Fig.22 is a graph showing sound reduction effects as a function of sound frequencies in Examples 15 through 18;

Figs.23 to 26 are vertical sectional side views showing Examples 19 through 22 in each of which a device of the present invention is applied to guide vanes in a bending portion of a flow passage;

Fig.27 is a graph showing sound reduction effects as a function of sound frequencies in Examples 19 through 22;

Fig.28 is a vertical sectional side view showing Example 23 in which a device of the present invention is applied to a pantagraph for an electric vehicle;

Fig.29 is a graph representing sound reduction effect attained by Example 23 in which a comparison is made between the example with fibers and a comparative example without fibers;

Fig.30 is a vertical sectional side view showing Example 24 in which a device of the present invention is applied to a stepped portion or a depressed portion on the surface of a vehicle or aircraft;

Fig.31 is a vertical sectional side view showing Example 25 in which a device of the present invention is applied to a projected portion on the surface of a vehicle or aircraft;

Fig.32 is a perspective view showing a rotor of a helicopter in Examples 26 and 27 to which a device of the present invention is applied;

Figs.33A and 33B are views showing a blade end of the rotor blade in Example 26, specifically, Fig.33A is a top view of the blade end with a side view thereof viewed from the length-wise direction of the blade while Fig.33B is a front view of the blade end;

Figs.34A and 34B are views showing a blade end of the rotor in Example 27; specifically, Fig.34A is a top view of the blade end with a side view thereof viewed from the length-wise direction of the blade, while Fig.34B is a front view of the blade end;

Fig.35 is a perspective view showing a rotor of a helicopter in Examples 28 and 29 to which a device of the present invention is applied;

Figs.36A and 36B are views showing a blade end of the rotor blade in Example 28, specifically, Fig.36A is a top view of the blade end with a side view thereof viewed from the length-wise direction of the blade while Fig.36B is a front view of the blade end;

Figs.37A and 37B are views showing a blade end of the rotor blade in Example 29, specifically, Fig.37A is a top view of the blade end with a side view thereof viewed from the length-wise direction of the blade while Fig.37B is a front view of the blade end;

Figs.38A and 38B are a front view and an overall vertical sectional side view showing Example 30 in which a device of the present invention is applied to a fan or rotor for an air conditioner;

Figs.39A and 39B are vertical sectional side view showing Example 31 in which a device of the present invention is applied to guide plates in an air conditioner;

Fig.40 is a vertical sectional side view showing Example 32 in which a device of the present invention is applied to a duct or pipe;

Fig.41 is a vertical sectional side view showing Example 33 in which a device of the present invention is applied to an area downstream of a projected object in a duct or pipe;

Fig.42 is a vertical sectional side view showing Example 34 in which a device of the present invention is applied to an area downstream of a valve in a pipe;

Figs.43 and 44 are diagrams illustrating mechanisms of generation of fluxional force sound; and

Figs 45A to 45D are illustrations showing conventional measures for reducing fluxional force-generated sound.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Basic configurations of fluxional force-generated sound reduce devices of the present invention

will hereinafter be explained with reference to Examples 1 through 11 shown in Figs.1 to 11. Further, specific examples will be described in Examples 11 through 34 wherein devices of the present invention are applied to a fluid blow-off opening, a collector positioned downstream of a blow-off opening, guide vanes provided in a flow passage, a vehicle or aircraft, rotor blades of a helicopter, an air conditioner, an inside surface of a duct or pipe, and a valve inside a pipe. It should be noted that the scope of the present invention will not be limited to these specific examples but is intended to include all variations and modifications which could be conceived based on the disclosure of the present application and the appended claims by those skilled in the art

(Example 1)

Fig.1 shows Example 1 of a fluxional force-generated sound reducing device of the present invention. In the figure, reference numeral 1 designates an object moving relative to a fluid (for example, aircrafts, vehicles, automobiles, chimneys, submarines, ships, wings, air blowers, helicopter rotor blades, propellers), and the surface of the object 1 is covered with fine fibers 5 which form a fur-like layer.

The fine fibers 5 can be directly planted onto the surface of the object 1 by one of conventional methods. Alternatively, a fur-like material which comprises fibers and a base sheet material may be affixed on the surface of the object 1. The fluid may be either liquid or gas or a mixture of both.

(Example 2)

Fig.2 shows Example 2 of a fluxional force-generated sound reducing device of the present invention. In the figure, designated at 2 is a pipe or duct conveying a fluid which is exemplified as a wind tunnel nozzle in the figure. A fur-like material with a base sheet material and fine fibers 5 planted thereon is affixed on the inside surface of the pipe 2. The fluid may be either a liquid or gas. Fig.3 shows the effect of reduction in fluxional force-generated sound in Example 2. From the graph shown, it is understood that, in particular, high-frequency components of the sound can sharply be reduced by the device of the invention.

(Example 3)

Fig.4 shows Example 3 of a fluxional force-generated sound reducing device of the present invention. In the figure, designated at 1 is an object moving relative to a fluid. The surface of the object 1 is covered with a porous material 6 whose surface has fine fibers 5 planted thereon.

(Example 4)

Fig.5 shows Example 4 of a fluxional force-generated sound reducing device of the present invention. In the figure, designated at 2 is a pipe or duct (such as, for example, a wind tunnel collector, a diffuser, etc.) conveying a fluid. The inside surface of the pipe 2 is covered with a porous material 6 whose surface is furred with fine fibers 5.

(Example 5)

Fig.6 shows Example 5 of a fluxional force-generated sound reducing device of the present invention. In the figure, designated at 16 is an object moving relative to a fluid. In this example, the object 16 itself is formed of a porous material and covered on its surface with fine fibers 5. This example is preferably used for fan blades or the like.

(Example 6)

Fig.7 shows Example 6 of a fluxional force-generated sound reducing device of the present invention. In the figure, designated at 26 is a pipe or duct. The pipe or duct 26 is covered with a porous material 6 which is in turn covered on its inside surface with fine fibers 5. Further, arranged on one end of the pipe or duct 26 is a pipe or duct (a wind tunnel nozzle) 21 (see the duct 2 shown in Fig.2) while a pipe or duct 22 (see the duct 2 shown in Fig.5) conveying a fluid is disposed on the other end of the pipe or duct 26. This example is preferably applied to a case in which generated sound from a testing piece set inside a pipe or duct is difficult to externally measure because the inside surface of the pipe or duct itself generates considerable noises; that is, this configuration can preferably be used for a case, for example, in which aerodynamic sound generation is tested using a sound passing duct at an instrumental barrel portion of a wind tunnel.

(Example 7)

Fig.8 shows Example 7 of a fluxional force-generated sound reducing device of the present invention. In the figure, designated at 1 is an object moving relative to a fluid. A member with fine fibers 5 planted thereon is provided in a trailing edge of the object 1.

(Example 8)

Fig.9 shows Example 8 of a fluxional force-generated sound reducing device of the present invention. In the figure, designated at 21 is a pipe or duct (a wind tunnel nozzle) conveying a fluid. Fine fibers 5 are disposed around the outlet edge of the pipe or duct 21.

(Example 9)

Fig.10 shows Example 9 of a fluxional force-generated sound reducing device of the present invention. In the figure, designated at 1 is an object moving relative to a fluid. A porous member 6 with fine fibers 5 planted thereon is joined to a trailing edge of the object 1.

(Example 10)

Fig.11 shows Example 10 of a fluxional force-generated sound reducing device of the present invention. In the figure, designated at 21 is a pipe or duct (a blow-off nozzle) conveying a fluid. Fine fibers 5 are disposed around the outlet edge of the pipe or duct 21.

Next, descriptions will be made about the operations of the fluxional force-generated sound reducing device according to the present invention.

In the cases where fine fibers 5 are furred on the surface of an object 1 or the inside surface of a pipe 2, etc. as shown in Figs.1 through 7:

1) When a turbulent flow 1 from the upstream side collides with the object surface or the inside surface of the pipe, etc., the fine fibers 5 function as a cushion so as to soften the vortexes colliding with the surface, thereby reducing pressure fluctuations.

2) The boundary layer near the surface of the object 1 or the inside surface of the pipe 2, etc. may easily be transformed into a turbulent flow by the fine fibers 5 so that the turbulence becomes less spatially correlated in the flow. Further, when any generated turbulent flow passes by, pressure fluctuations can be reduced in the same manner as described above.

3) Each fiber is very fine and soft, therefore does not exert any reaction forces (or any pressure fluctuations) against the flow. As a result, sound arising when the flow collides with the fibers is softened to a considerable extent.

4) When fine fibers 5 are placed on a porous member 6 covering a rigid object or pipe or when an object or pipe is made from a porous material 6 itself with fine fibers 5 planted thereon, the porous material 6 adds a further cushioning effect. Besides, the porous material has functions of absorbing pressure fluctuations and allowing the fluid to permeate itself to the rear side thereof, whereby the fluxional force-generated sound can be further reduced.

In the cases where fine fibers 5 are provided on a trailing edge of an object 1 or an opening end portion of a pipe 2, etc. as shown in Figs.8 through 11:

5) The boundary between the object (a rigid body) and the fluid is made obscure, so that the generation of strong trailing vortexes is prevented.

6) In the above case, the sound generated from the fine fibers 5 themselves can be reduced to a large extent because of the same reason described in 1) right above.

7) When a porous member is joined to the trailing edge of the object 1 or the end portion of the pipe 2, etc. with fine fibers 5 planted thereon, the above effect can be further enhanced and the absorbing effect by a pressure fluctuation itself generated therearound can be expected.

<u>Examples 11 through 18</u>

<u>Applications of the present invention to a wind tunnel with a blow-off opening</u>

(Examples 11 to 14)

<u>Applications of the present invention to a blow-off opening</u>

Figs.12 through 15 show applications of the present invention to a blow-off opening.

(Example 11)

Fig.12 shows Example 11 according to the present invention for a contracted barrel 32 having a blow-off opening on the downstream side thereof and connected to a duct 33. In this example, fine fibers or a fur-like material 31 with fine fibers planted thereon is affixed on the entire inside surface of the contracted barrel 32. The contracted barrel may be made of either a rigid material or a sound absorbing material consisting of porous material. The fine fibers or fur-like material may be affixed directly on the inside surface of the contracted barrel by a method shown in manner (a) in the figure. Alternatively, the material can be affixed on the inside surface as shown in manner (b) so that the surface of the material may be connected substantially in level with the duct surface. Denoted by 'D' is a representative diameter of the blow-off opening. The duct 33 and the contracted barrel 32 in this example are used, for example, in a wind tunnel.

(Example 12)

Fig.13 shows Example 12 of a contracted barrel 32 having a blow-off opening on the downstream side thereof. In this example, fine fibers or fur-like material 31 with fine fibers planted thereon is affixed on the part of the inside surface of the contracted barrel 32 between an inflection point 34 and the blow-off opening. The portion of the contracted barrel with the material 31 affixed thereon may be made of either a rigid material or a sound absorbing material consisting of porous material. The fine fibers or fur-like material may be affixed directly on the inside surface of the contracted barrel by a method shown in manner (a) in the figure. Alternatively, the material can be affixed on the inside surface as shown in manner (b) so that the surface of the material may be connected substantially in level with the conducted barrel surface.

(Example 13)

Fig.14 shows Example 13 of a contracted barrel 32 having a blow-off opening on the downstream side thereof. In this example, fine fibers or fur-like material 31 with fine fibers planted thereon is affixed on the whole part of the inside surface of the contracted barrel 32 between a point which is positioned apart by a distance 'X' downstream of an inflection point 34 and the blow-off opening. The portion of the contracted barrel with the material 31 affixed thereon may be made of either a rigid material or a sound absorbing material consisting of porous material. The fine fibers or fur-like material may be affixed directly on the inside surface of the contracted barrel by a method shown in manner (a) in the figure. Alternatively, the material can be affixed on the inside surface as shown in manner (b) so that the surface of the material may be connected substantially in level with the contracted barrel surface. Fig.15 is a graph schematically showing the relationship between the distance 'X' and noise reduction. The units of the abscissa and ordinate axes in the graph are arbitrarily taken.

(Example 14)

Fig.16 shows Example 14 of a contracted barrel 32 having a flange 35 in the outlet portion thereof. In this example, fine fibers or fur-like material 31 with fine fibers planted thereon is affixed on the surface of the flange 35 facing the downstream side. The flange as well as the portion of the contracted barrel with the material 31 affixed thereon may be made of either a rigid material or a sound absorbing material consisting of porous material. The fine fibers or fur-like material may be trimmed in a manner shown in manner (a) so that the edge of the contracted barrel is substantially leveled with the material. Alternatively, the material may be extended inside the contracted barrel as shown in manner (b). Further, the extended portion affixed on the inside surface of the barrel may be formed as shown in manner (c) so that the surface of the material may be connected substantially in level with the inside surface of the contracted barrel.

Fig.17 shows results of measurements on the sound reduction effect as a function of sound frequencies in Examples 11 through 14 shown in Figs.12 to 14 and 16, respectively. The measurement was made at a point, as shown in Fig.12, away from the end of the blow-off opening by the distance 'D' in a downstream direction from the blowout opening, and off by 1.5D from the axis of the barrel, where D denotes the representative diameter of the blowout opening. The flow speed of the fluid in the blow-off opening when the measurement was done was 83.4m/s.

Examples 11 through 14 can be applied, for example, to a wind tunnel.

(Examples 15 through 18)

Applications of the present invention to a collector positioned downstream of a blow-off opening of a wind tunnel

Figs.18 through 21 show applications of the present invention to a collector disposed downstream of a blow-off opening of a duct.

Fig.18 shows Example 15 of a pipe having a collector 36, a straight pipe portion 37 having a constant cross-section and a diffuser 38 downstream of the straight pipe portion. In this example, fine fibers or a fur-like material 31 with fine fibers planted thereon is affixed on the entire inside surface of the pipe. In the Fig.18, a contracted barrel 32 is depicted upstream of the collector 36 in order to clarify the positional relation therebetween.

Figs.19A and 19B show Example 16 of a pipe having a collector 36, a straight pipe portion 37, and a diffuser 38. The diffuser 38 is made of a porous material for sound absorption. The contracted barrel 32 is omitted in these figures. In this example, fine fibers or a fur-like material 31 with fine fibers planted thereon is affixed on the entire inside surfaces of the collector 36, the straight pipe portion 37 and the diffuser 38 (Fig.19A). Alternatively, the material 31 is affixed on the entire inside surfaces of the collector 36 and the straight pipe portion 37 and on a part of the diffuser 38 (Fig.19B). In the case where the fine fibers or fur-like material is affixed on a part of the diffuser 38, the material should be affixed in a range of from the upstream end of the diffuser to a reattachment

point of the flow after flow separation. Practical dimensions of the fur-like material affixed portion vary depending upon features of wind tunnels.

Figs.20A and 20B show Example 17 of a pipe having a collector 36, a straight pipe portion 37 and a diffuser 38. In this example, fine fibers or fur-like material 31 with fine fibers planted thereon is affixed on the inside surfaces of the collector 36 and the straight pipe portion 37. The collector 36 and the straight pipe portion 37 may be made of either a rigid material (Fig.20A) or a sound absorbing material consisting of porous material (Fig.20B).

Figs.21A and 21B show Example 17 of a pipe having a collector 36, a straight pipe portion 37 and a diffuser 38. In this example, fine fibers or fur-like material 31 with fine fibers planted thereon is affixed on only the inside surface of the collector 36. The collector 36 may be made of either a rigid material (Fig.21A) or a sound absorbing material consisting of porous material (Fig.21B).

Fig.22 shows measured results of sound reduction effects in the examples shown in Figs.18 to 21, more specifically, with configurations shown in Figs.18, 19B, 20A, and 21A. The measurement was made at a point shown in Fig.18, which is equivalent to that shown in Fig.12. The flow speed in the blow-off opening at the measurement was 83.4m/s, which is identical with that at the measurement shown in Fig.17.

(Examples 19 through 22)

Applications of the present invention to guide vanes

Figs.23 through 26 show applications of the present invention to guide vanes in a bending portion of a flow passage.

Fig.23 shows Example 19 in which fine fibers or a fur-like material 31 with fine fibers planted thereon is affixed on the entire surface of guide vanes 40 disposed in a bent portion 41 of a flow passage. The guide vanes 40 may be made of either a rigid material or a sound absorbing material consisting of porous material.

Fig.24 shows Example 20 in which fine fibers or a fur-like material 31 with fine fibers planted thereon is affixed on upstream ends and thereabout of guide vanes 40. The material is preferably affixed on both sides of each guide vane 40 in a range of from the upstream end of the guide vane 40 down to a position one-forth of the vane length. The guide vanes 40 may be made of either a rigid material or a sound absorbing material consisting of porous material.

Fig.25 shows Example 21 in which fine fibers or a fur-like material 31 with fine fibers planted thereon is affixed only on upstream ends of guide vanes 40. The guide vanes 40 may be made of either a rigid material or a sound absorbing material consisting of porous material.

Fig.26 shows Example 22 in which fine fibers or a fur-like material 31 with fine fibers planted thereon is affixed only on upstream ends and concave sides of guide vanes 40. That is, almost all part of the convex side of each guide vane 40 has no fur-like material 31 affixed. The guide vanes 40 may be made of either a rigid material or a sound absorbing material consisting of porous material.

Fig.27 shows measurements of sound reduction effects in the examples shown in Figs.13 to 26. The measurement was made at a point shown in Fig.23, where 'D' is the representative diameter of the duct. The main-flow speed at the time of measurement was 60m/s.

(Examples 23 through 25)

Applications of the present invention to vehicles and aircraft

Figs.28 through 31 show applications of the present invention to vehicles and aircraft.

Fig.28 shows Example 23 in which fine fibers or a fur-like material 31 with fine fibers planted thereon is affixed on a pantagraph 52 disposed on the top of a vehicle body 51. Fig.29 shows measurements of sound reduction effects in this example. The measurement was made at a point away from the pantagraph by 1 m in a lateral direction. The main-flow speed at the measurement was 60m/s.

Figs.30 and 31 show Example 24 and 25, respectively, in which fine fibers or a fur-like material 31 with fine fibers planted thereon is affixed on a stepped portion or depressed portion 54 (Fig.30) or on a projection 55 (Fig.31). Fig.30 shows Example 24 in which the fur-like material 31 is affixed on a stepped portion or depressed portion on the surface of a vehicle or aircraft. Fig.31 shows Example 25 in which the fur-like material is affixed on a projection on the surface of a vehicle or aircraft. The affix range of the fur-like material 31 in Fig.31 is preferably extended to cover up to a point at a distance ten times the projection height 'h' away from the projection 55. Here, the fur-like material 31 may be applied directly on the surface as shown in Fig.31 or may be applied so that the surface of the fiber material is substantially leveled with the body surface having no fiber material by machining the part of the body surface to which the material 31 is to be affixed.

(Examples 26 through 29)

Applications of the present invention to rotor blades of a helicopter

Figs.32 through 37 show applications of the present invention to main-rotor blades or other rotor blades of a helicopter.

Fig.32 shows Examples 26 and 27 in which fine fibers or fur-like material 31 with fine fibers planted thereon is affixed on blade ends of main rotor blades 56 or other rotor blades. Figs.33A to 34B are enlarged views of a portion designated at 57 in Fig.32. Figs.33A and 34A are top views of a blade and Figs.33B and 34B are front views of a blade viewed along a direction facing the moving direction of the blade. The fur-like material 31 may be affixed on the whole of the blade end as shown in Figs.33A and 33B or only on an upstream portion of the blade end as shown in Figs.34A and 34B. The surface of the blade to which the fur-like material is affixed may be made of either a rigid material or a porous material. Here, the fur-like material 31 may be applied directly on the blade surface as shown in the figures or may be applied so that the surface of the fiber material is substantially leveled with the blade surface with no fiber material by machining the part of the blade surface to which the material 31 is to be affixed. In Figs.33A and 34A, L1 and L2 denote lengths of the affix part of the fur-like material. The lengths are preferably one to two times the thickness of the blade. A length designated at L3 in Fig.34B is preferably more or less equal to the thickness of the blade.

Fig.35 shows Examples 28 and 29 in which fine fibers or fur-like material 31 with fine fibers planted thereon is affixed on front edges of main or other rotor blades 56. The fur-like material 31 may be affixed on the full length of the front edge or on a front edge part between the middle of the blade and the blade end. The fibers or fur-like material may be adapted to cover only the front edge of the blade with the blade end side uncovered (Figs.36A and 36B) or may cover a portion of the blade end side as well as the front edge (Figs.37A and 37B). Figs.36A and 36B as well as 37A and 37B are enlarged views of a portion designated at 57' in Fig.35, and correspond to Figs.33A to 34B. The surface of the blade to which the fur-like material or fiber material is affixed may be made of either a rigid material or a porous material. Here, the fur-like material 31 may be applied directly on the blade surface as shown in the figures or may be applied so that the surface of the fiber material is substantially leveled with the blade surface with no fiber material by machining the part of the blade surface to which the material 31 is to be affixed. Lengths L4 and L5 in Figs.36A and 37A are preferably almost equal to the thickness of the blade.

(Examples 30 and 31)

Applications of the present invention to an air conditioner

Figs.38A and 38B and Figs.39A and 39B show applications of the present invention to an air conditioner.

Figs.38A,38B show Example 30 in which fine fibers or fur-like material 31 with fine fibers planted thereon is affixed on supporting beams 59 for a fan or rotor 58 in an air conditioner. Fig.38A is a front view of the supporting beams 59. The entire part on the front side of the supporting beams 59 is covered with fur-like material 31. Fig.38B is a sectional side view showing the fan or rotor 58 in the air conditioner and the supporting beams 59 for the fun 58. The fur-like material 31 may be affixed only on the front side of the supporting beams 59 as shown in the figures or on the whole part of the supporting beams 59. The surface of the supporting beams 59 to which the fur-like material is affixed may be made of either a rigid material or a porous material. Here, the fur-like material 31 may be applied directly on the surface of the supporting beams 59 as shown in the figures or may be applied so that the surface of the fiber material is substantially leveled with the surface of the supporting beams 59 with no fiber material by machining the part of the surface of the supporting beams 59 to which the material 31 is to be affixed.

Fig.39A shows Example 31 in which fine fibers or a fur-like material 31 with fine fibers planted thereon is affixed on air-guide plates 60 positioned downstream of the fan or rotor 58 in an air conditioner. Fig.39B is an enlarged view of one of the guide plates 60 shown in Fig.39A. The fiber material may be affixed only on a front edge and flow-guiding part of the guide plate 60 or on the whole part of the guide plate 60. The surface of the guide plate 60 to which the fur-like material is affixed may be made of either a rigid material or a porous material.

(Examples 32 and 33)

Applications of the present invention to the inside surface of a duct or pipe

Figs.40 and 41 show applications of the present invention to the inside surface of a duct or pipe. Fig.40 shows Example 32 in which fine fibers or a fur-like material 31 with fine fibers planted thereon is affixed on the entire inside wall 61 of a duct or pipe. The material of the duct or pipe to

which the fibers or fur-like material is affixed may be made of either a rigid material or a sound absorbing material consisting of porous material. It is also possible to use a sound absorber composed of a rigid material base and a porous material layered thereon.

Fig.41 shows Example 33 in which fine fibers or a fur-like material 31 with fine fibers planted thereon is affixed on a part on the inside wall of a duct or pipe 61 where the flow is fluctuated by an object 62. The object may be attached directly on the wall surface of the duct or pipe 61 as shown in the figure or may be supported by an unillustrated supporting member inside the flow in the duct or pipe 61. The fiber material is preferably affixed in a range L within which the turbulence factor measured at 5 mm inside the boundary wall is twenty times greater than the same factor in another regions inside the tube. The inside wall surface of the duct or pipe to which the fiber material is affixed may be made of either a rigid material or a sound absorbing material 63 consisting of porous material as shown in the figure.

(Example 34)

Application of the present invention to a portion downstream of a valve in a pipe

Fig.42 shows Example 32 in which fine fibers or a fur-like material 31 with fine fibers planted thereon is affixed on the inside surface of a pipe or duct 65 on the downstream of a valve 64 used inside the pipe. The fluid which passes through the valve 64 may be gas such as air or liquid such as water. The fibers or fur-like material should be affixed in a range M within which the turbulence factor measured at 5 mm inside the boundary wall of the pipe or duct 65 is thirty times greater than the same factor on the upstream side of the valve 64. The material 31 is preferably affixed immediately downstream of a valve plug 66. The inside wall surface of the duct or pipe to which the fiber material is affixed may be made of either a rigid material or a porous material.

Claims

1. A fluxional force-generated sound reducing device for reducing noise generated by fluxional forces acting on an object contacting a fluid and moving relative to the fluid or a pipe or duct conveying a fluid, comprising:

   a fur-like portion having fine fibers planted on at least a part of a surface of said object or said pipe or duct which surface comes in contact with the fluid.

2. A fluxional force-generated sound reducing device according to claim 1, wherein said fur-like portion is formed by disposing a fur-like material comprising a base sheet material and fine fibers planted on the base sheet material.

3. A fluxional force-generated sound reducing device for reducing noise generated by fluxional forces acting on an object contacting a fluid and moving relative to the fluid or a pipe or duct conveying a fluid, comprising:

   a porous material layer covering at least a part of a surface of said object or said pipe or duct which surface comes into contact with the fluid; and

   a fur-like portion having fine fibers planted on at least a part of a surface of said porous material layer.

4. A fluxional force-generated sound reducing device according to claim 3,, wherein said fur-like portion is formed by disposing a fur-like material comprising a base sheet material and fine fibers planted on the base sheet material on the surface of the porous material layer.

5. A fluxional force-generated sound reducing device according to claim 1, wherein at least a part of said object or said pipe or duct whose surface contacts the fluid is made of a porous material.

6. A fluxional force-generated sound reducing device according to claim 5, wherein said fur-like portion is formed by disposing a fur-like material comprising a base sheet material and fine fibers planted on the base sheet material.

7. A fluxional force-generated sound reducing device according to claim 1, wherein said part of the surface is located around either a trailing edge of the object or an open end portion of the pipe or duct.

8. A fluxional force-generated sound reducing device according to claim 7, wherein a top surface formed said fine fibers is substantially leveled with a surface or said object or said pipe of duct at surface boundary between a portion covered by said fine fibers and a neighboring portion not covered by said fine fibers.

9. A fluxional force-generated sound reducing device according to claim 7, wherein a porous material layer is provided at the trailing edge or at the open end portion and said fur-like portion is provided on a surface of said porous

material layer.

10. A method of reducing sound generated by fluxional forces acting on an object contacting a fluid and moving relative to the fluid or a pipe or duct conveying a fluid, comprising the step of planting fine fibers on at least a part of a surface of said object or said pipe or duct which surface comes into contact with the fluid, so as to form a fur-like portion.

11. A method of reducing fluxional force-generated sound according to claim 10, wherein said fur-like portion is formed by disposing a fur-like material comprising a base sheet material and fine fibers planted on the base sheet material.

12. An object contacting a fluid and moving relative to the fluid, comprising a fur-like portion having fine fibers planted on at least a part of an object surface contacting the fluid, so as to reduce sound generated by fluxional forces acting on said object.

13. A pipe conveying a fluid therethrough, comprising a fur-like portion having fine fibers planted on at least a part of an inside pipe surface contacting the fluid, so as to reduce sound generated by fluxional forces acting on an inside surface of said pipe.

14. A pipe according to claim 13, wherein said pipe is a contracted barrel connected to a duct.

15. A pipe according to claim 13, wherein said pipe is a collector disposed downstream of a blow-off opening of a duct.

16. An object according to claim 12, wherein said object comprises guide vanes in a bending portion of a flow passage.

17. An object according to claim 12, wherein said object is a pantagraph for an electric vehicle.

18. An object according to claim 12, wherein said object is a vehicle or aircraft.

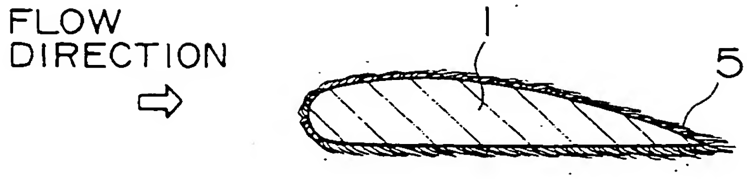
19. An object according to claim 12, wherein said object comprises rotor blades.

20. An object according to claim 19, wherein said object comprises rotor blades for a helicopter.

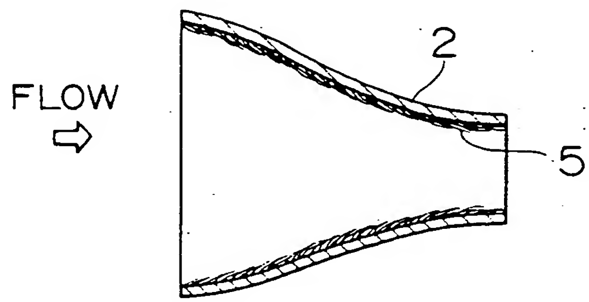
21. An object according to claim 12, wherein said object comprises supporting beams supporting fan.

22. A pipe according to claim 13, wherein said pipe is located immediately downstream of a valve plug.

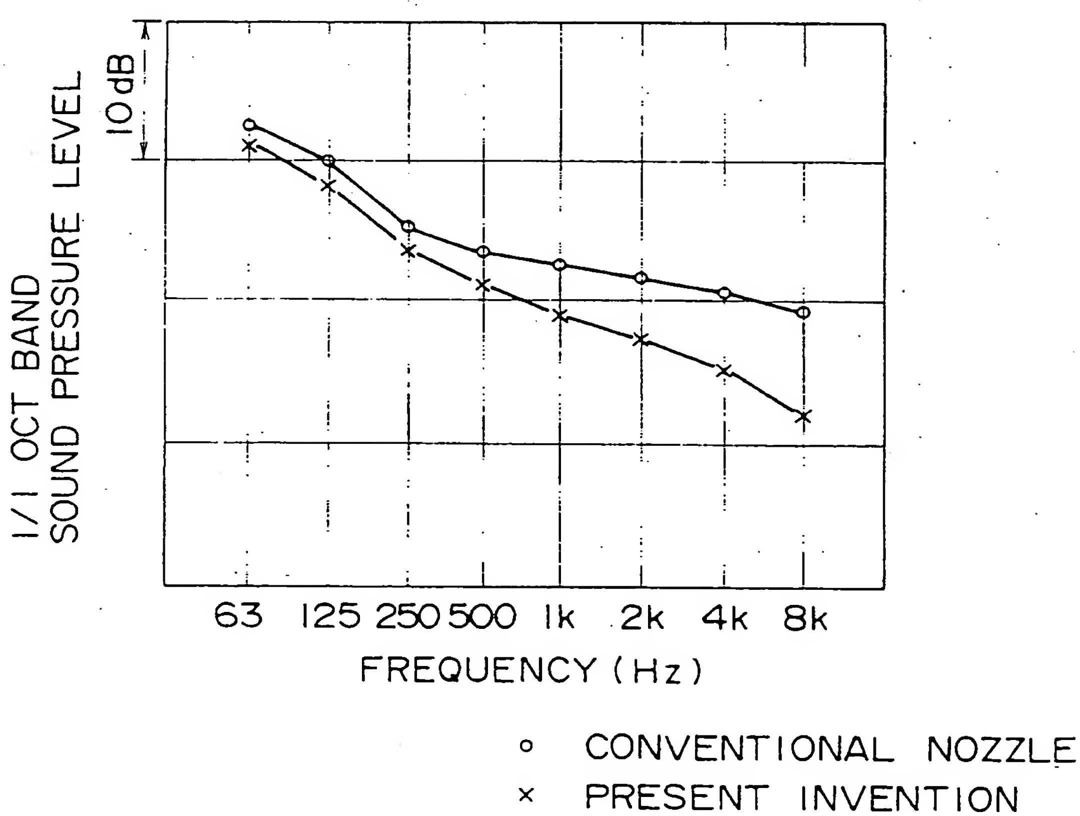
F I G. 1



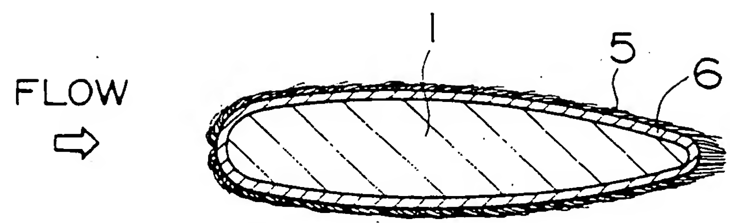
F I G. 2



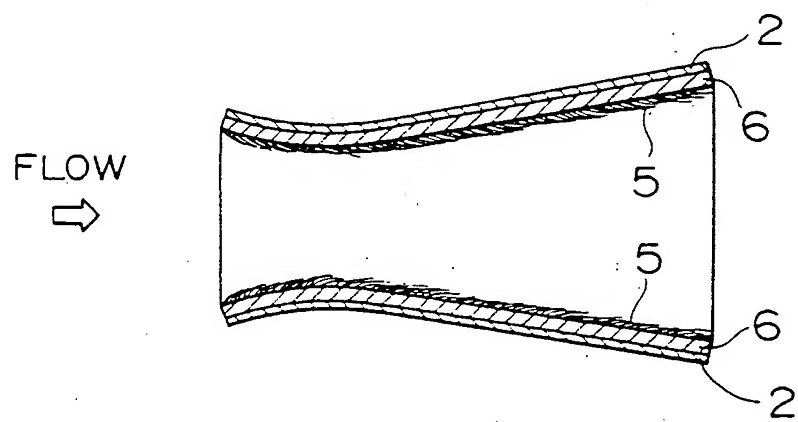
F I G. 3



F I G. 4



F I G. 5



F I G. 6

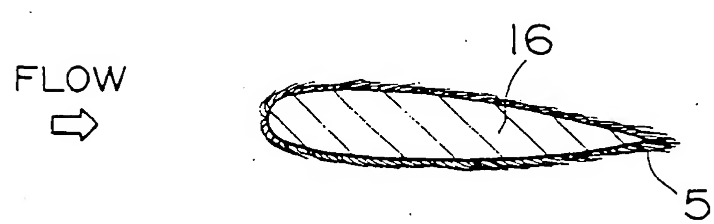


FIG. 7

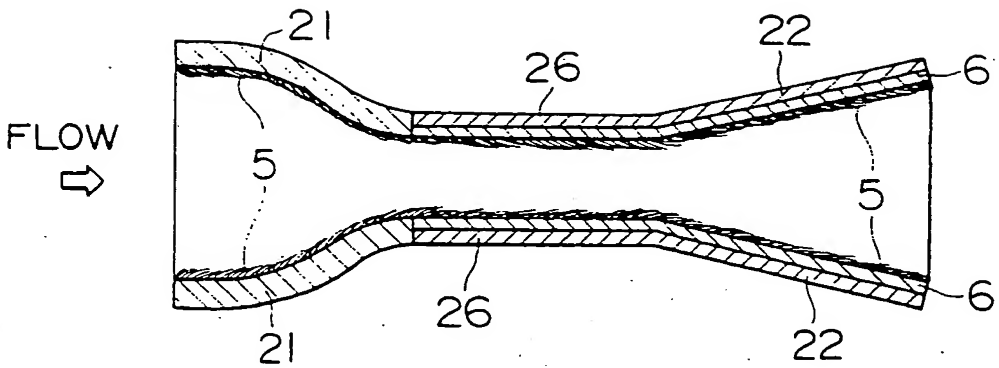


FIG. 8

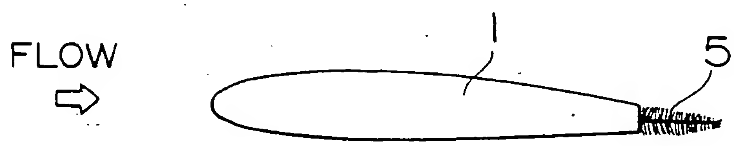


FIG. 9

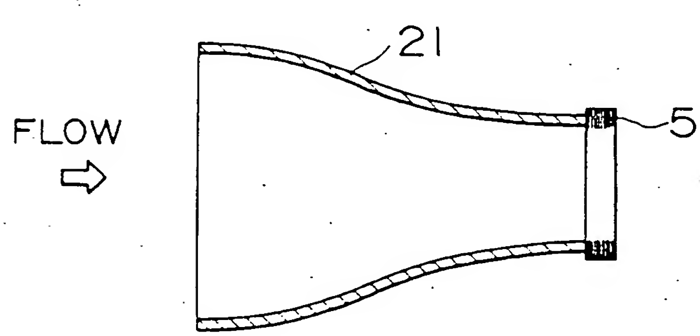
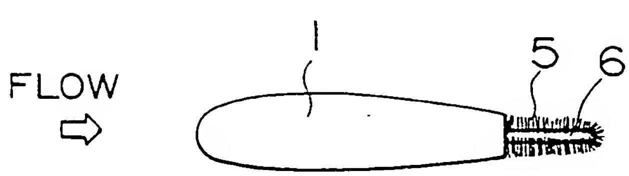
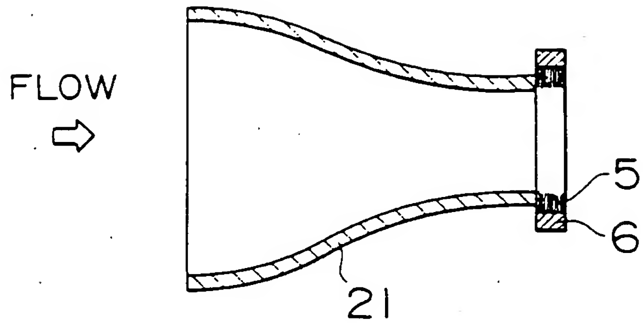


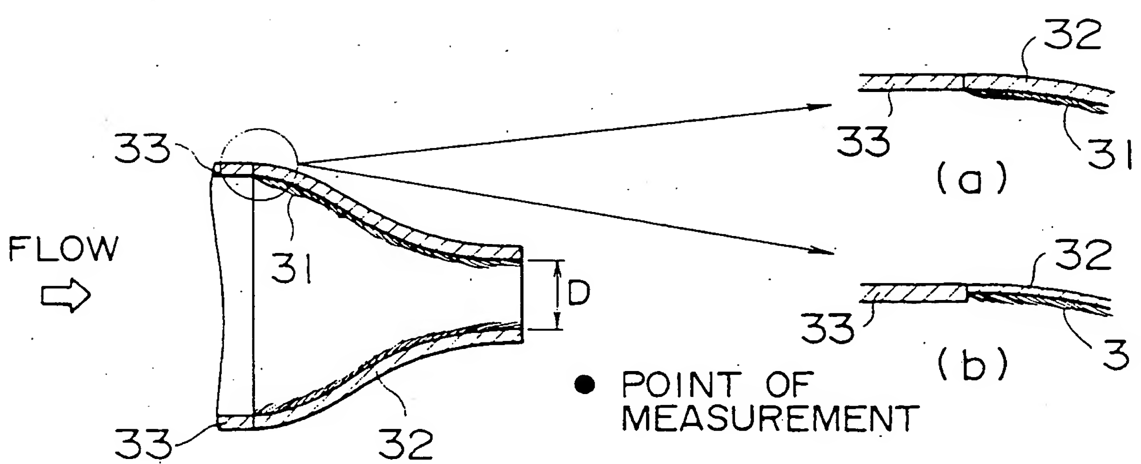
FIG. 10



F I G. 11



F I G. 12



F I G. 13

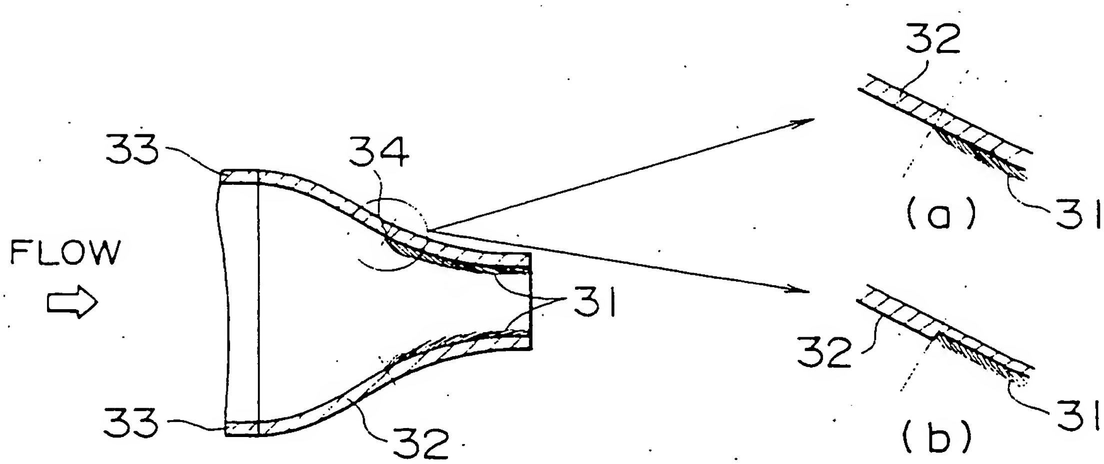


FIG. 14

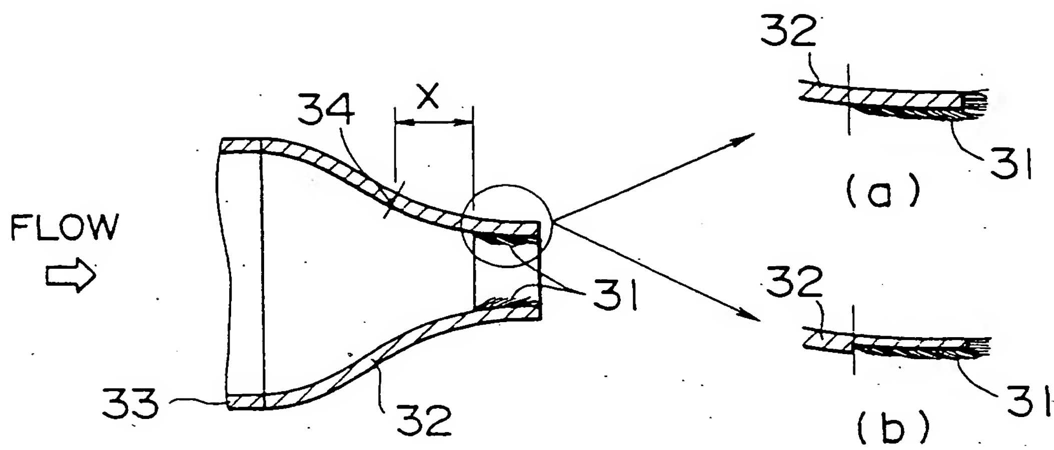

32
34
X
31
(a)
FLOW
32
31
33
32
31
(b)

FIG. 15

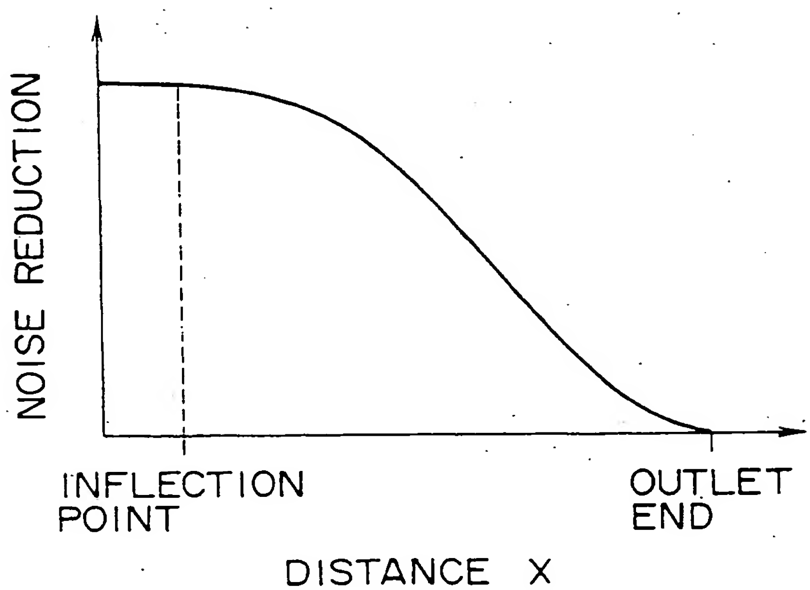
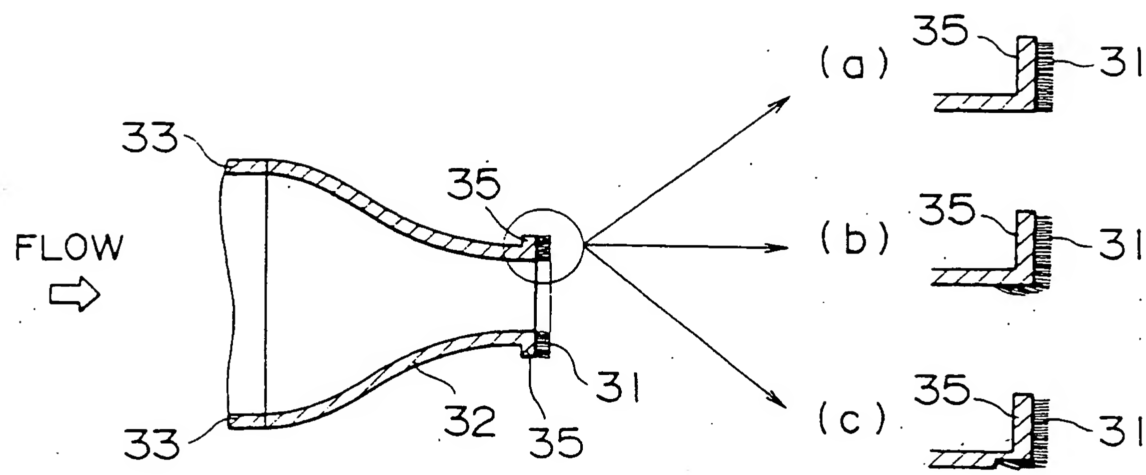
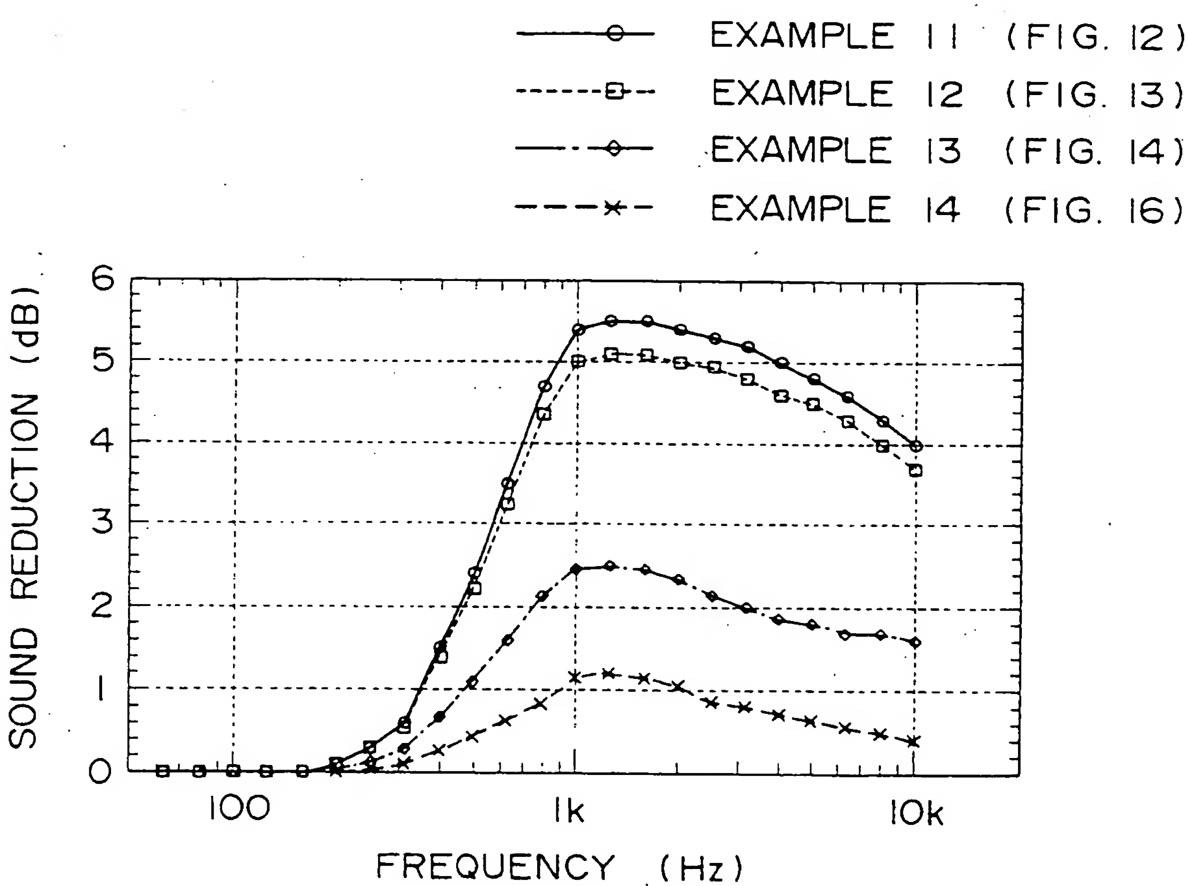

NOISE REDUCTION
INFLECTION POINT
OUTLET END
DISTANCE X

FIG. 16



FLOW
33
33
35
32
35
31
(a)
35
31
(b)
35
31
(c)
35
31

FIG. 17



EXAMPLE 11 (FIG. 12)
EXAMPLE 12 (FIG. 13)
EXAMPLE 13 (FIG. 14)
EXAMPLE 14 (FIG. 16)
SOUND REDUCTION (dB)
0
1
2
3
4
5
6
100
1k
10k
FREQUENCY (Hz)

FIG. 18

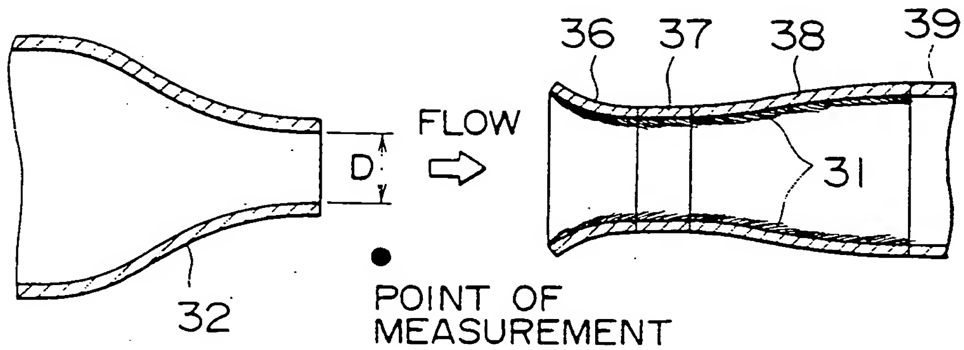


FIG. 19A

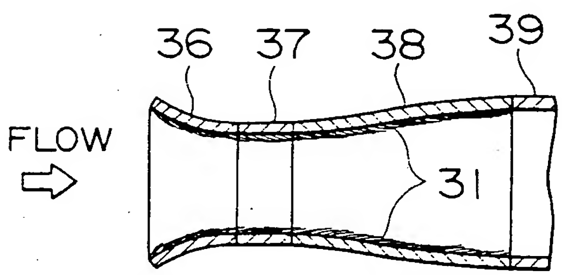


FIG. 19B

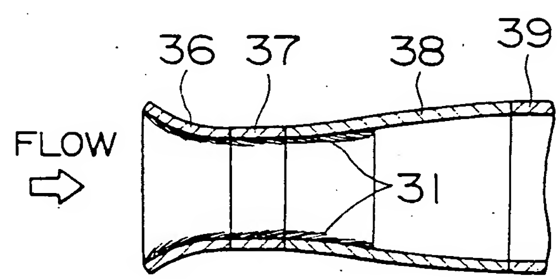


FIG. 20A

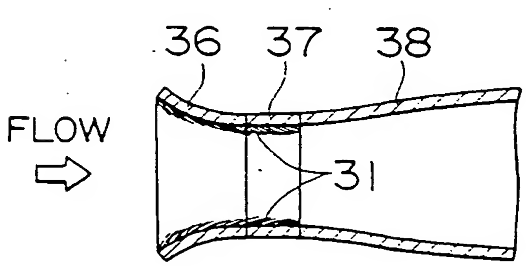


FIG. 20B

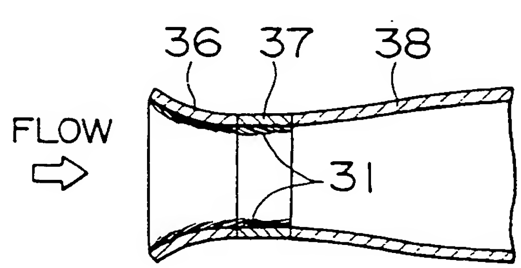


FIG. 21A

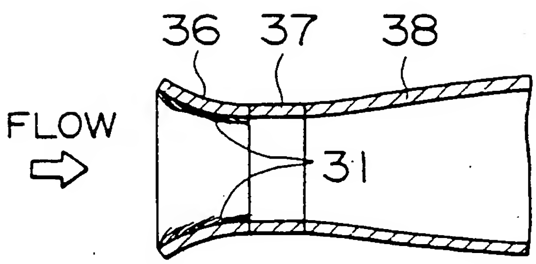


FIG. 21B

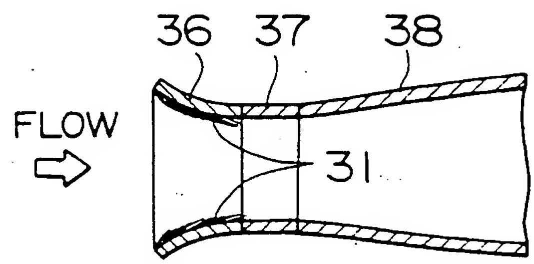


FIG. 22

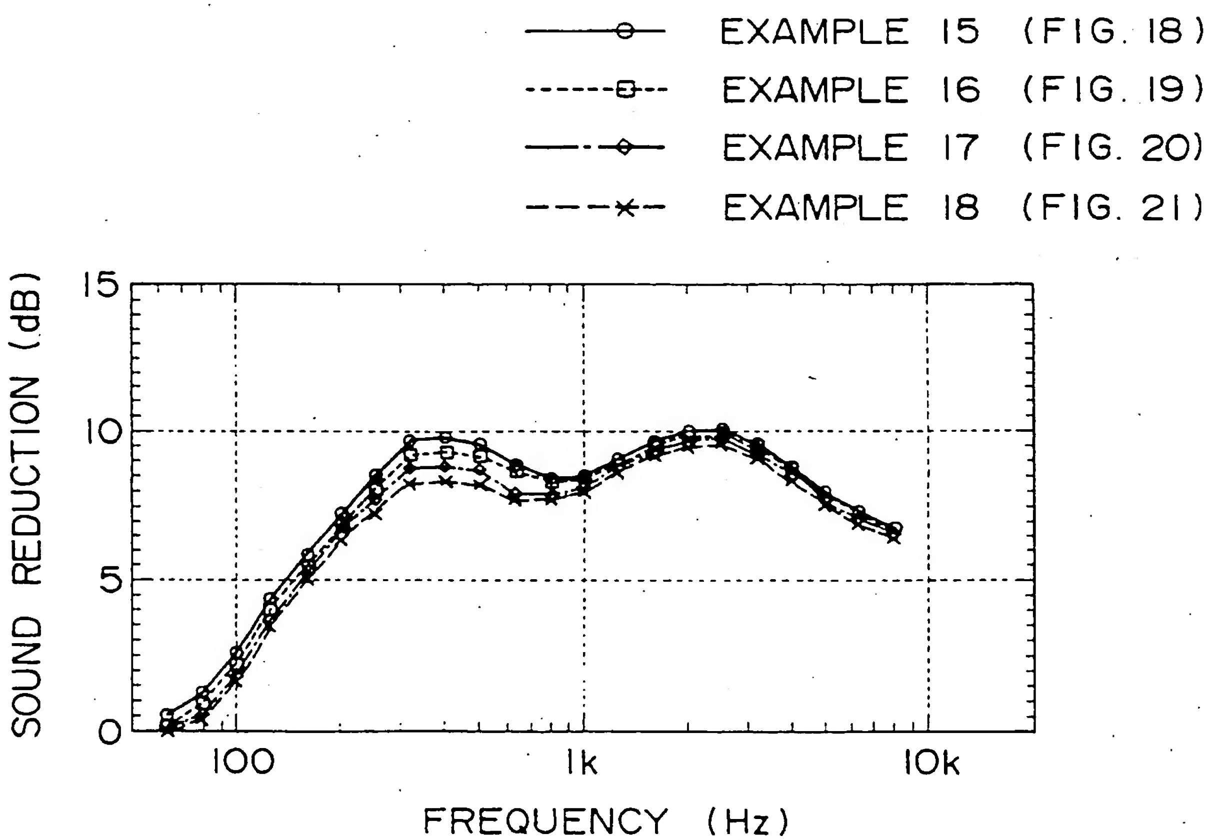


FIG. 23

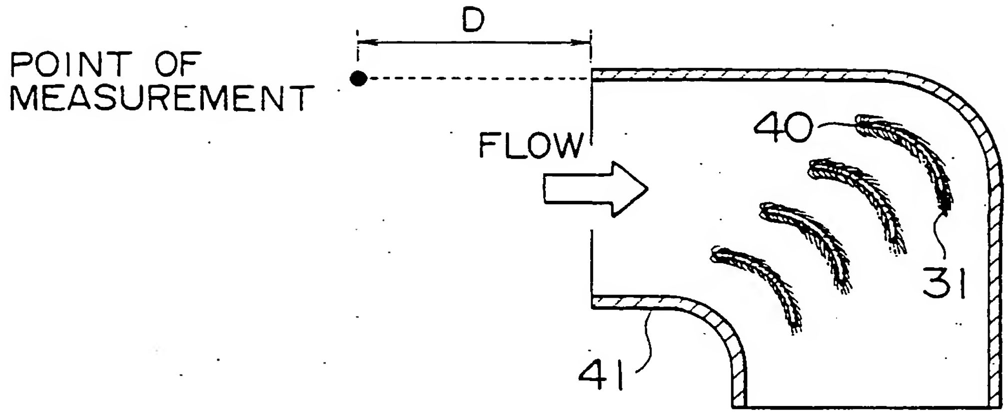


FIG. 24

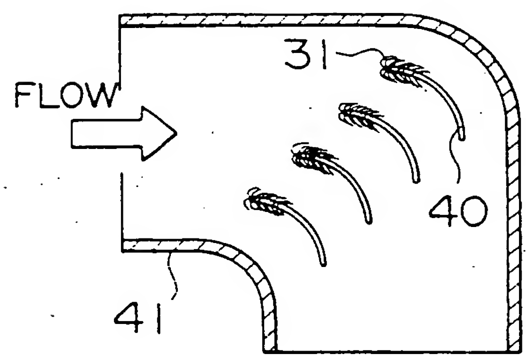


FIG. 25

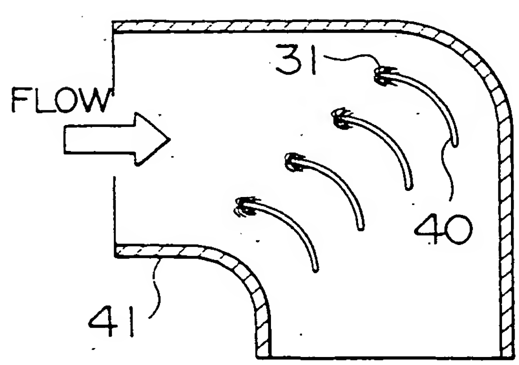


FIG. 26

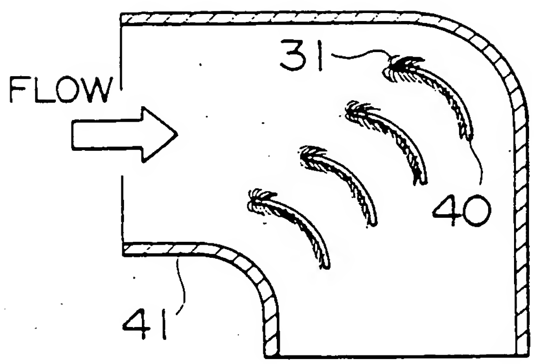

FLOW
31
40
41

FIG. 27

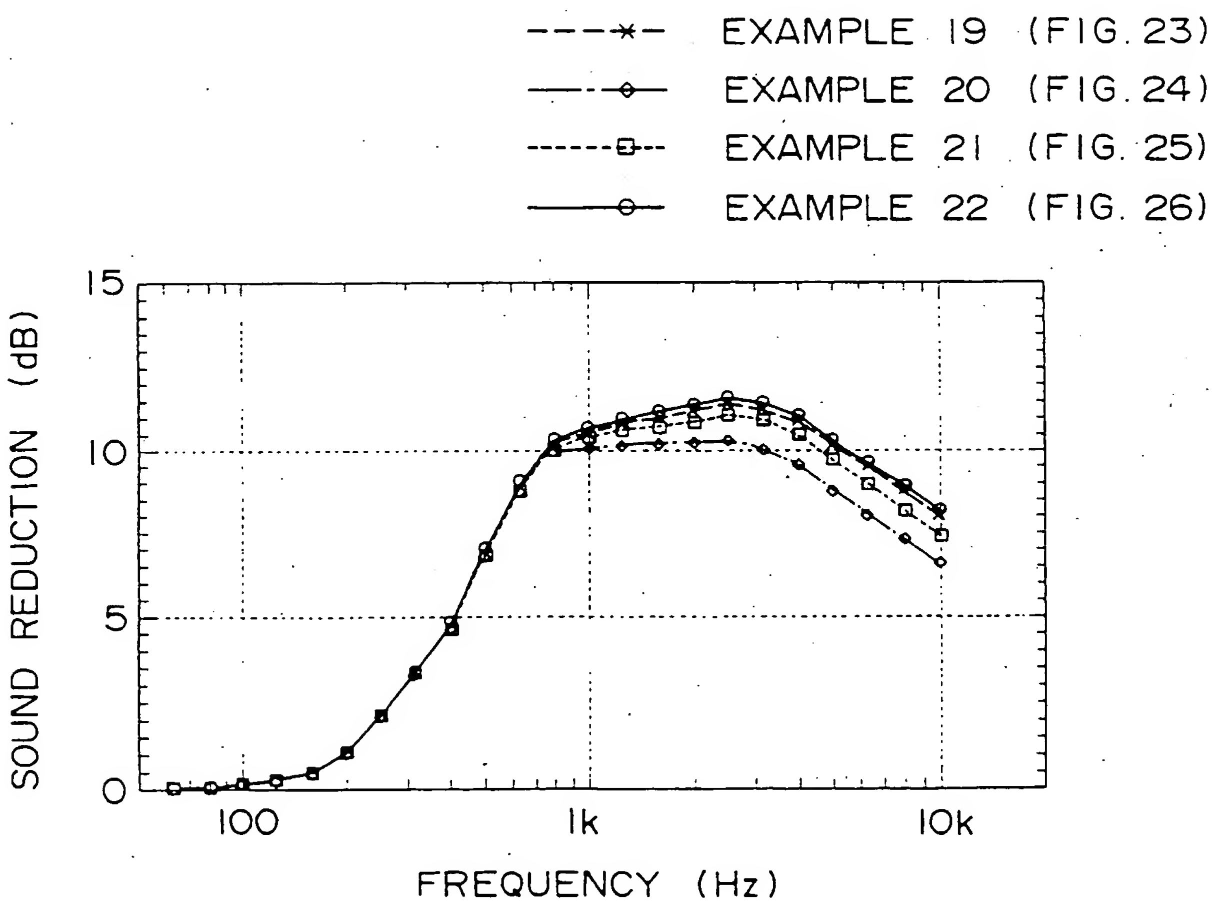

EXAMPLE 19 (FIG. 23)
EXAMPLE 20 (FIG. 24)
EXAMPLE 21 (FIG. 25)
EXAMPLE 22 (FIG. 26)
15
10
5
0
SOUND REDUCTION (dB)
100
1k
10k
FREQUENCY (Hz)

FIG. 28

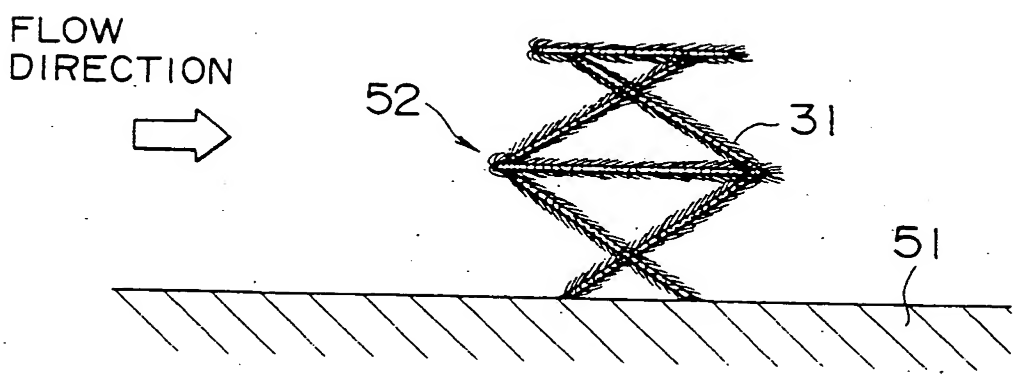

FLOW
DIRECTION
52
31
51

FIG. 29

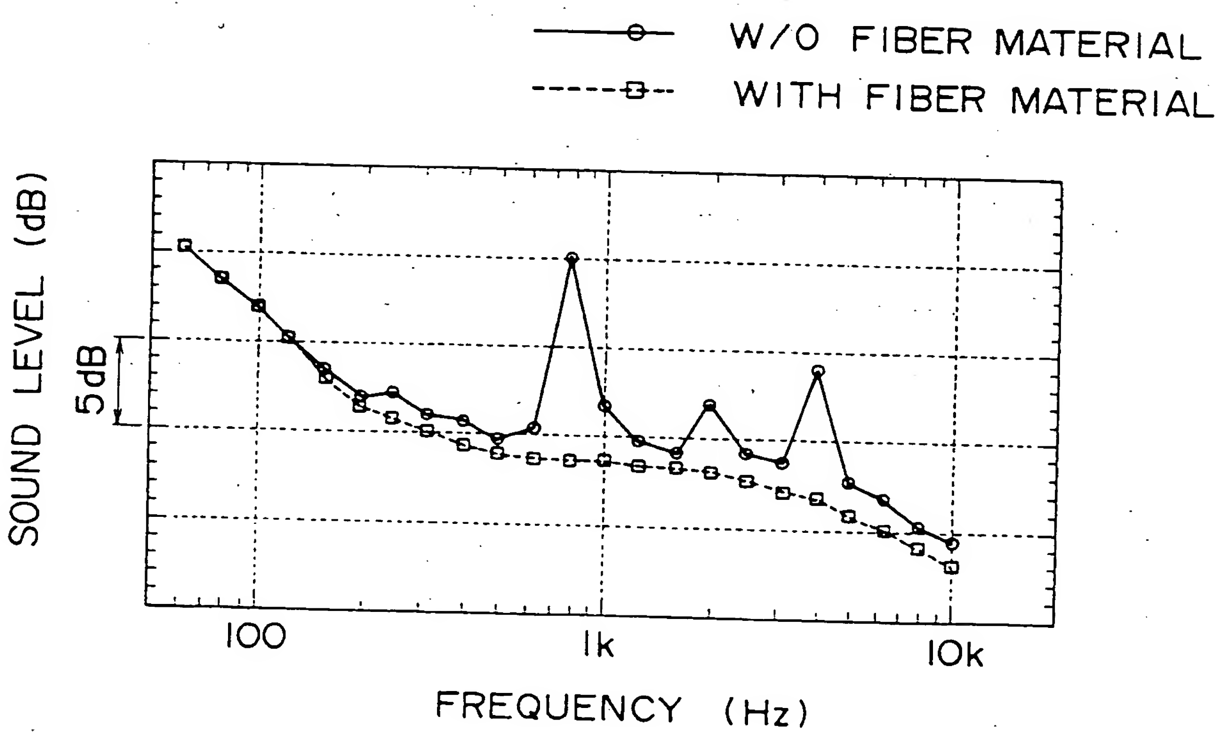

W/O FIBER MATERIAL
WITH FIBER MATERIAL
SOUND LEVEL (dB)
5dB
100
1k
10k
FREQUENCY (Hz)

FIG. 30

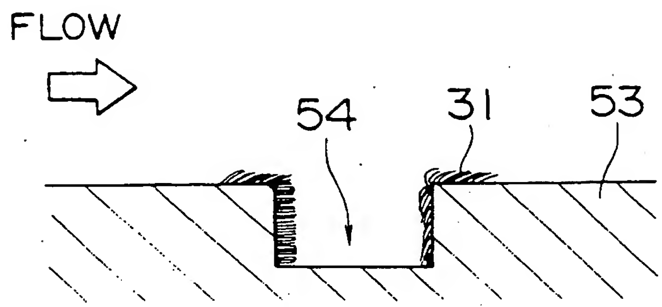
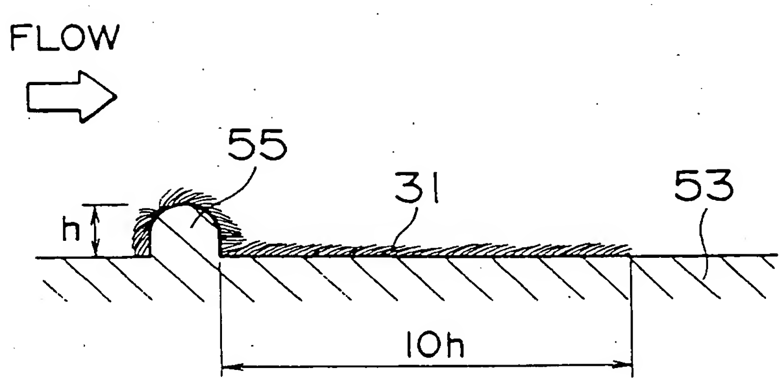
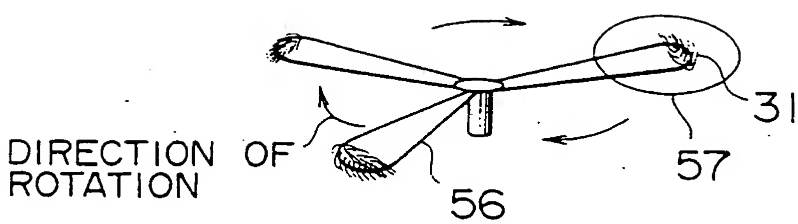


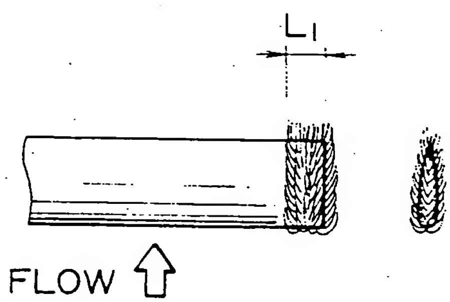
FIG. 31



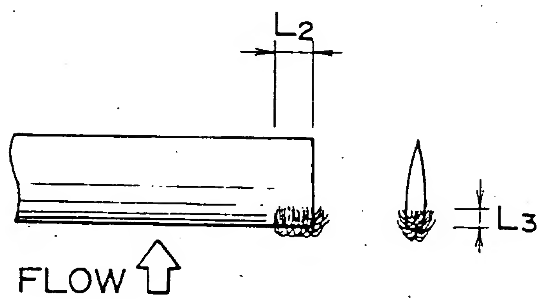
F I G. 32



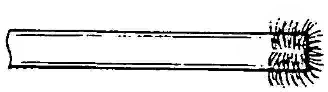
F I G. 33A



F I G. 34A



F I G. 33B



F I G. 34B

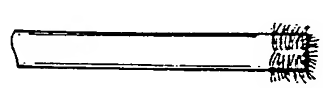


FIG. 35

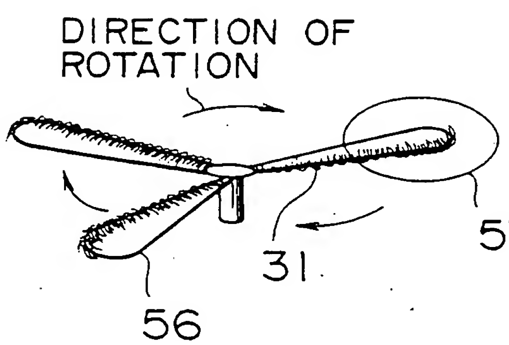


FIG. 36A

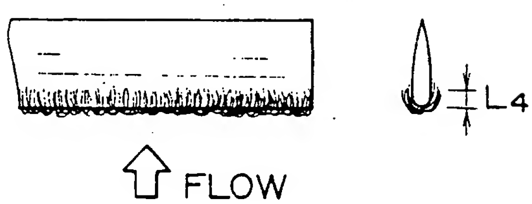


FIG. 37A

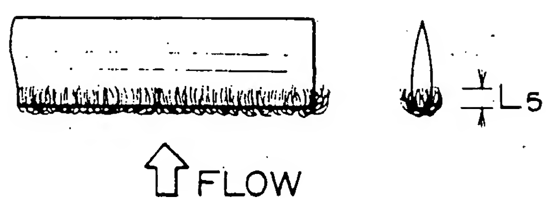


FIG. 36B

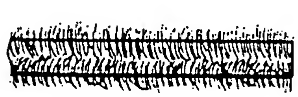
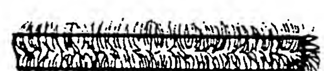
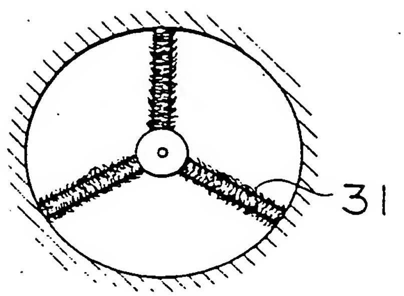


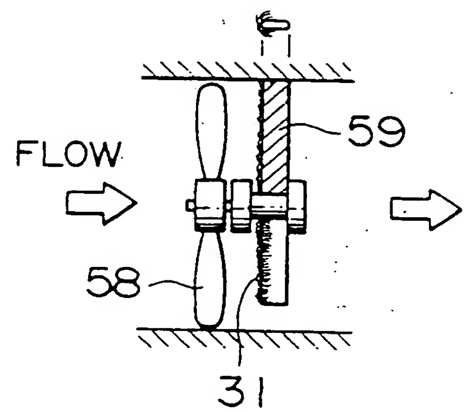
FIG. 37B



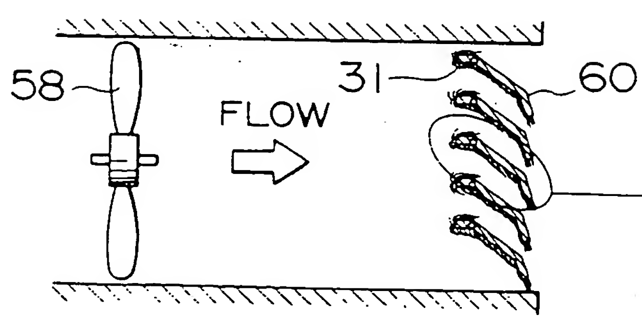
F I G. 38A



F I G. 38B



F I G. 39A



F I G. 39B

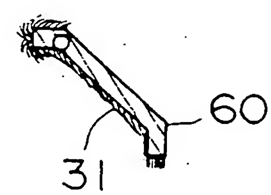


FIG. 40

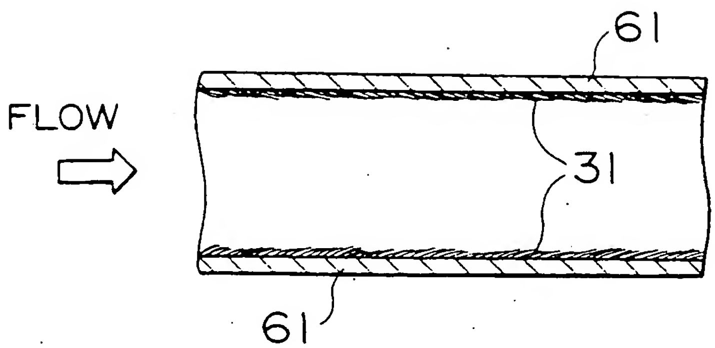


FIG. 41

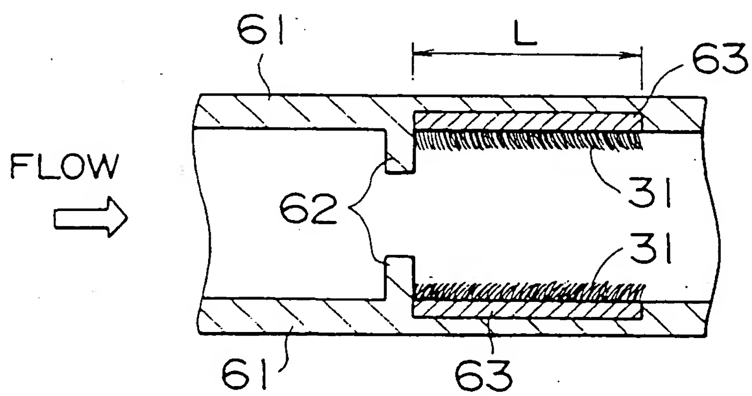


FIG. 42

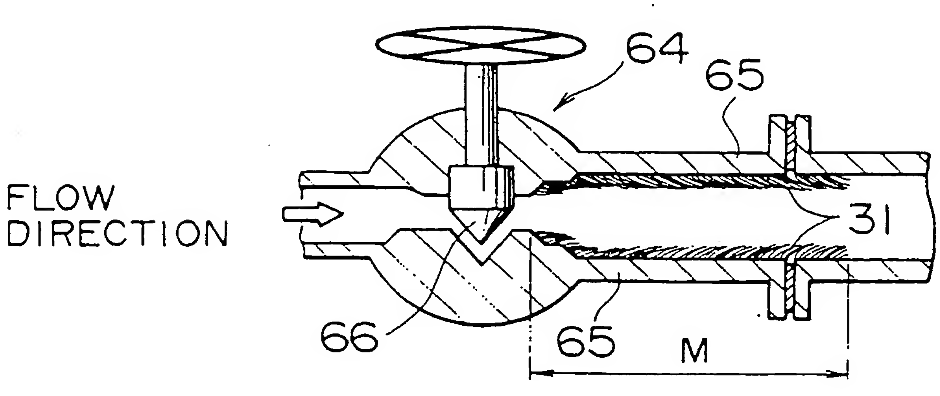


FIG. 43

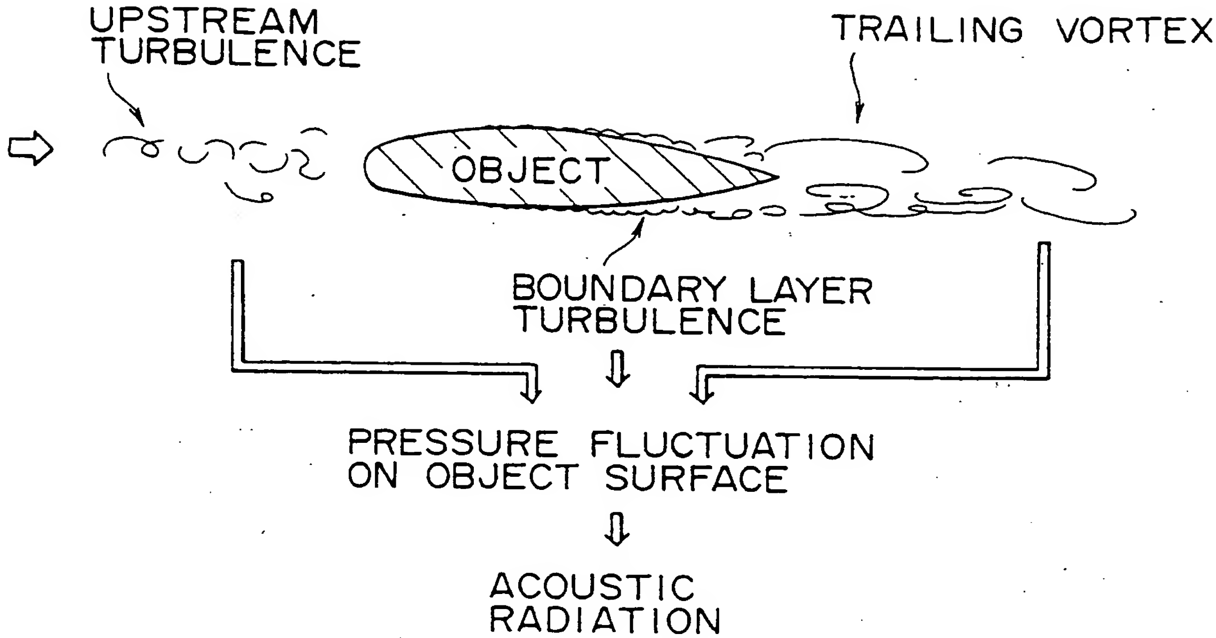

UPSTREAM TURBULENCE
TRAILING VORTEX
OBJECT
BOUNDARY LAYER TURBULENCE
PRESSURE FLUCTUATION ON OBJECT SURFACE
ACOUSTIC RADIATION

FIG. 44

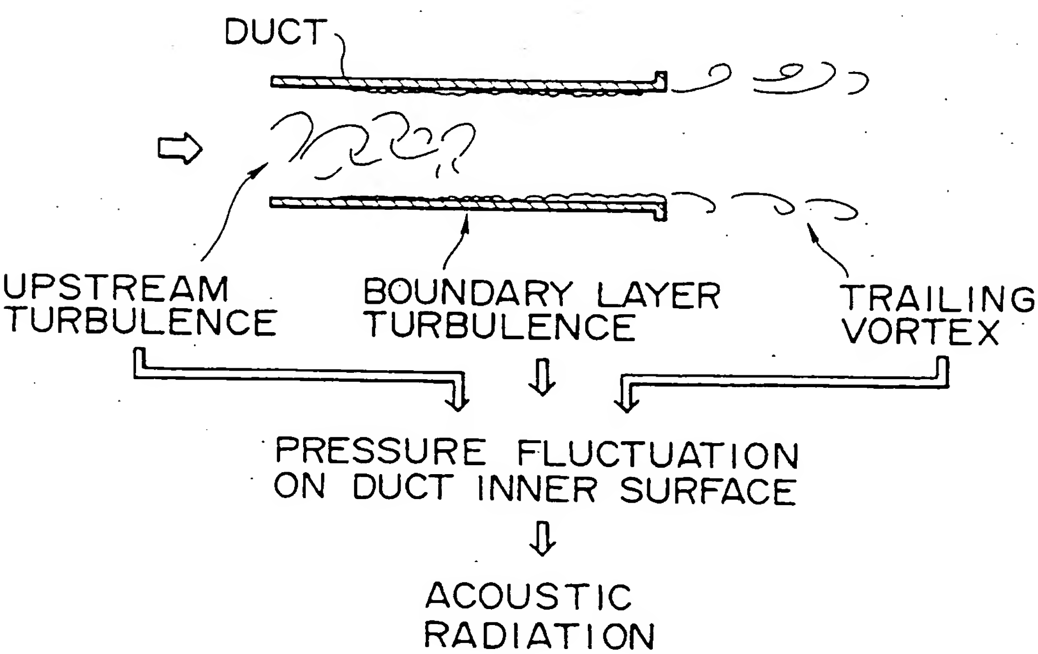

DUCT
UPSTREAM TURBULENCE
BOUNDARY LAYER TURBULENCE
TRAILING VORTEX
PRESSURE FLUCTUATION ON DUCT INNER SURFACE
ACOUSTIC RADIATION

FIG. 45A

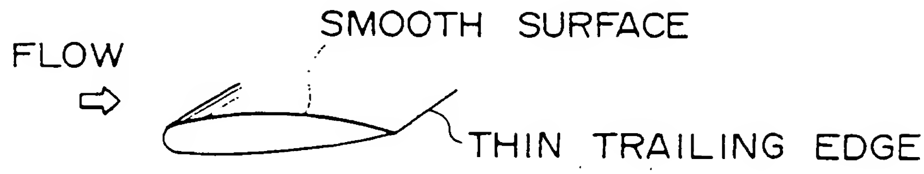


FIG. 45B

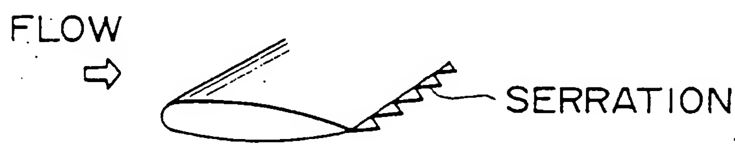


FIG. 45C

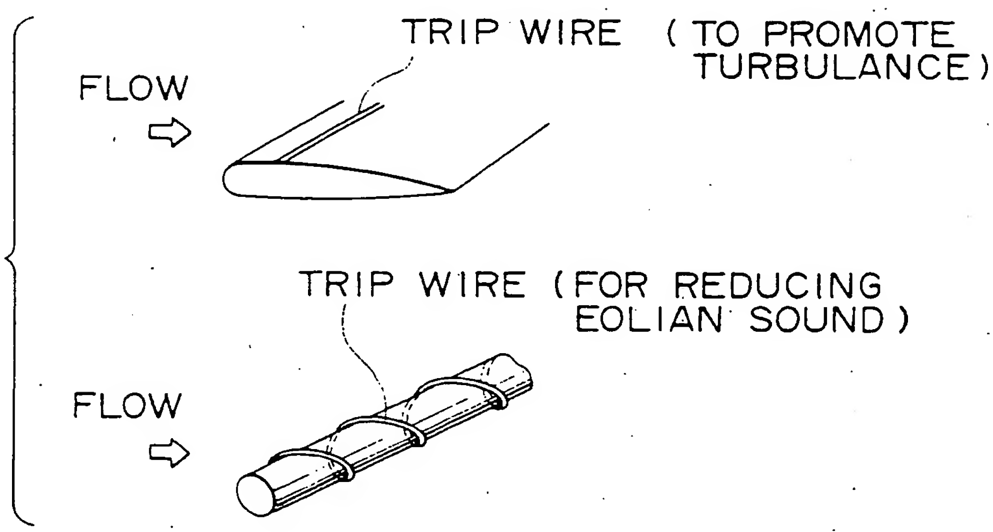
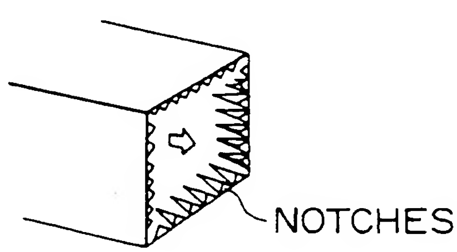


FIG. 45D



European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 94 11 9623

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	US-A-4 211 305 (MATTHEWS) * column 1, line 13 - line 38 * * column 1, line 45 - line 66 * * column 3, line 48 - line 62 * * column 4, line 27 - line 40 * * column 4, line 66 - column 5, line 30; figures 2,3,6-14 * ---	1-6, 10-13	B64C21/10 F15D1/06 F15D1/12 F04D29/22 F04D29/68 F01N1/24 F16L55/033
X	DE-A-37 10 691 (KECUR) * column 1, line 34 - line 44 * * column 2, line 5 - line 42 * * column 3, line 15 - line 22; figures 1-3 * * column 2, line 5 - line 42 * ---	1,2, 10-12,18	
A	US-A-2 322 632 (HARPER) * the whole document * ---	1-4,7, 10-12, 18,19	
A	US-A-1 903 823 (LOUGHEED) * page 1, line 1 - line 36 * * page 5, line 73 - page 6, line 44 * * page 6, line 74 - line 85; figures 5-10,13,14 * -----	1,3,5, 12,18-20	**TECHNICAL FIELDS SEARCHED (Int.Cl.6)** B64C F15D F04D F01N F16L B63B B63G

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	19 April 1995	Zeri, A

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